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# A PROGRESS REPORT ON FREEZING, STORAGE, AND DEFROSTING OF BREAD

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Summary. Freezer temperature was found to be the most important variable with respect to the freezing rate of wrapped bread; with unwrapped bread air velocity and loaf position were factors of major importance. Freshly baked unwrapped bread can be frozen relatively rapidly and without significant loss of moisture.

Defrosting rates are affected by humidity conditions as well as by air temperature, because both contribute to the heat-carrying capacity of the air. In addition, duration of exposure to defrosting conditions affects moisture changes at the surface of unwrapped bread during defrosting.

The advisability of freezing bread as soon as possible after it leaves the oven and of freezing and defrosting as rapidly as possible, economically, was confirmed by both physical and taste-panel results. Freezing time was found to affect crumb firmness more than defrosting time. Firming changes were found to continue at a slow rate at temperatures just below the freezing point. Maximum desirable storage temperatures were therefore concluded to be 10°F. or lower for short-term storage and 0°F. or lower for extended storage.

Frozen bread stored for more than a day or two should be wrapped in a sturdy, moisture-resistant material that is flexible at low temperatures. The shrinkage of bread during freezing increases the requirements to be met by satisfactory wrapping materials.

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# FREEZING, STORAGE, AND DEFROSTING OF BREAD

The investigations reported here were designed to aid in the selection of procedures and equipment for the baking, packaging, freezing, storage, and defrosting of bread.

## Freezing Rates

The importance of freezing quickly to preserve oven-fresh flavor and texture has been strongly emphasized in previous reports (1,2,5,6), but information on rate of freezing under various conditions is not extensive. Figure 1 shows the effect of air temperature on rate at which bread cooled and froze in an air blast of about 700 ft./min. These results represent 1.5-pound, unsliced, round-top loaves of white pan bread enclosed in waxed-paper wrappers. The bread was supported on wire-mesh trays and the long dimension of the loaves was parallel to the air stream. Center-loaf temperatures were measured with thermocouples and recorded automatically. Freezing times are times required for center-loaf temperature to fall from 70°F. to 20°F. The latter is the freezing point of white bread as determined in these experiments. Air velocity was measured with a pin-wheel anemometer in the empty chamber.

The freezing point (near 20°F.) is illustrated in Figure 1 by the horizontal portion of the curve obtained with a freezer temperature of 10°F. At lower freezer temperatures the bread froze more rapidly, so that this transition zone in the curves became distorted and progressively shortened as temperature was lowered. Freezing time decreased steadily with each decrease in freezer temperature, as expected, but even at the lowest used (-40°F.), approximately an hour and a half was required.

With wrappers removed and experimental conditions otherwise similar, the bread froze 10 to 30 minutes faster, with the larger effects at temperatures of 0°, -10°, and -20°F. The differences were about equal to those shown in Figure 1 for differences of about 10°F. in freezer temperature. Rates for wrapped and unwrapped bread at a lower air velocity (200 ft./min.) were similar except that freezing times at a given temperature were slightly longer--that is, 5 minutes longer with wrapped and about 15 minutes longer with unwrapped bread. This was the closest approach to still air that was used.

The cooling rate of wrapped bread was practically unaffected by changes in air velocity from 200 up to about 1,300 ft./min. Freezer temperature, therefore, is the more important variable for wrapped bread. With unwrapped, however, faster freezing occurred at 700 ft./min. than at 200 ft./min., but no further advantage was obtained by raising air velocity to about 1,300 ft./min., as long as the loaves were parallel to the air stream. When loaf position was changed, however, it had no effect on freezing rate of wrapped bread at all air velocities studied and only a slight effect with unwrapped bread at low and intermediate velocities, but a very marked increase in freezing rate was obtained when unwrapped loaves were oriented crosswise to air flow at about 1,300 ft./min.

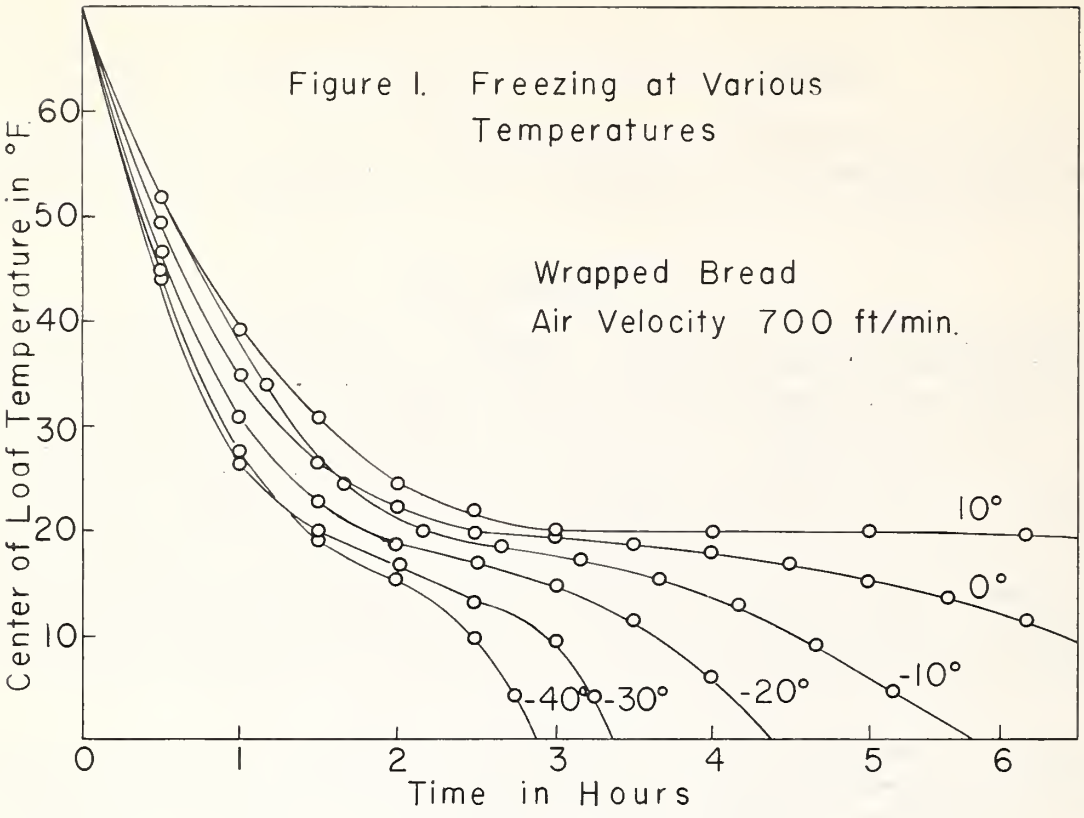
Figure I. Freezing at Various Temperatures
Wrapped Bread
Air Velocity 700 ft/min.
Center of Loaf Temperature in °F
Time in Hours
10°
0°
-10°
-20°
-30°
-40°
0
1
2
3
4
5
6
10
20
30
40
50
60

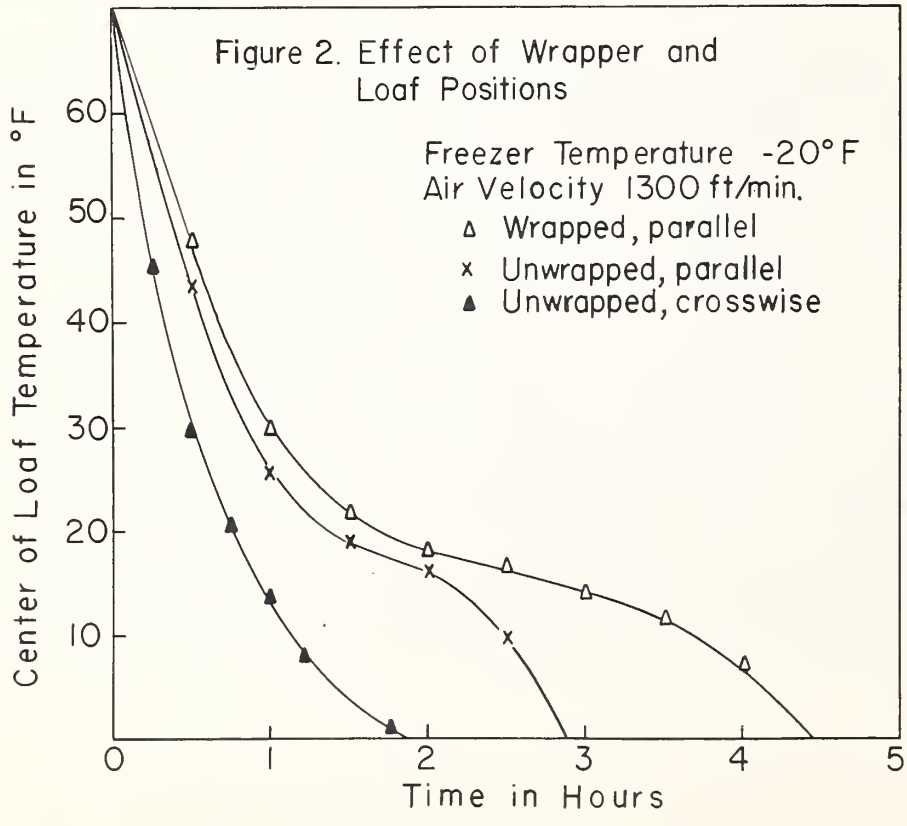
Figure 2. Effect of Wrapper and Loaf Positions
Freezer Temperature -20° F
Air Velocity 1300 ft/min.
Δ Wrapped, parallel
x Unwrapped, parallel
▲ Unwrapped, crosswise
Center of Loaf Temperature in °F
Time in Hours
0
1
2
3
4
5
10
20
30
40
50
60

Figure 2 summarizes some of the important comparisons discussed above. The first two curves show effect of the wrapper on freezing time, and the second and third show the effect of loaf position of unwrapped bread.

Although relatively rapid rates can be obtained by selected conditions, it must be emphasized that other aspects can offset the advantages gained. For instance, high air velocity may be just about as expensive as low temperatures. It is also possible that gains in quality retention may not be proportional to gains in freezing time. Nevertheless, observations show enough advantage for freezing bread without a wrapper that serious consideration should be given to it despite problems of getting the frozen bread sliced and into a wrapper. Both of the latter seem entirely feasible.

As a comparison with the foregoing results obtained with individual loaves on shelves, Figure 3 shows cooling curves for wrapped bread packed in a cardboard delivery carton. The boxed legend indicates position of loaves in the carton and the order in which they froze. The curves show cooling rates for three of the loaves, one in a corner position, one in a side position, and the other near the center. The difference in time between the corner and near-center loaves is more than 3 hours. Even with the loaf that froze fastest, a period of 5.5 hours was required, whereas a single loaf not packed in a carton required less than 2 hours under the same conditions (Figure 1).

Figure 4 shows cooling rates for other types of bread. Unwrapped, one-pound loaves were frozen at -20°F. while parallel to an air blast at 700 ft./min. A somewhat surprising result was the almost identical rates for white and 100% whole-wheat breads. Apparently, the large differences in volume and density were compensated by differences in other factors. Raisin bread cooled at about the same rate as white bread, but its actual freezing point was much lower, about 16°F. The sour French bread cooled much faster than the other breads, probably because of its long, narrow shape; its freezing point was approximately 22°F.

The differences in freezing points for different breads are probably related to sugar and salt contents. Sugars, such as the lactose in the milk solids and the sucrose remaining after fermentation depress the freezing points. Thus, the richer a formula, the lower the freezing point.

## Defrosting Rates

Studies of defrosting are not yet as extensive as those with freezing, but preliminary results demonstrate major factors that must be considered commercially. Defrosting time in these experiments is the time necessary for the temperature at the center of a loaf to rise from 0°F. to 70°F. In all cases the bread was stored a sufficient time at 0°F. for the temperature throughout the loaf to become uniform.

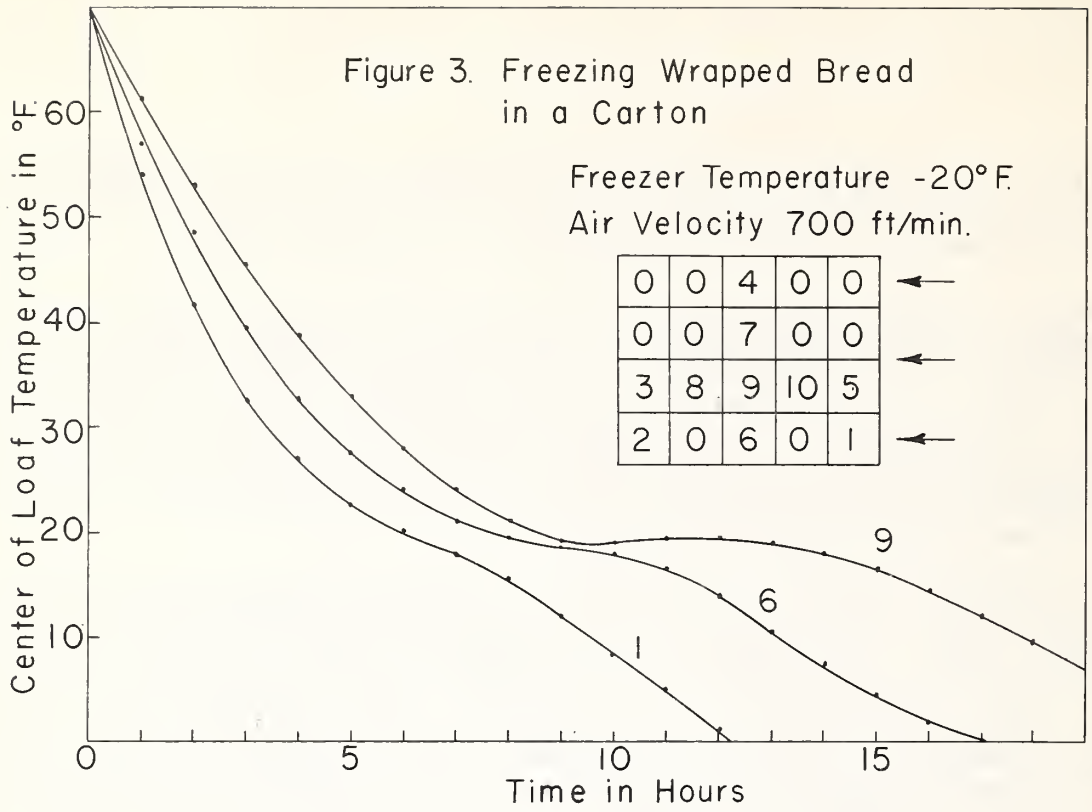
Figure 3. Freezing Wrapped Bread in a Carton
Freezer Temperature -20° F.
Air Velocity 700 ft/min.
0 0 4 0 0
0 0 7 0 0
3 8 9 10 5
2 0 6 0 1
9
6
1
Center of Loaf Temperature in °F.
60
50
40
30
20
10
0
5
10
15
Time in Hours

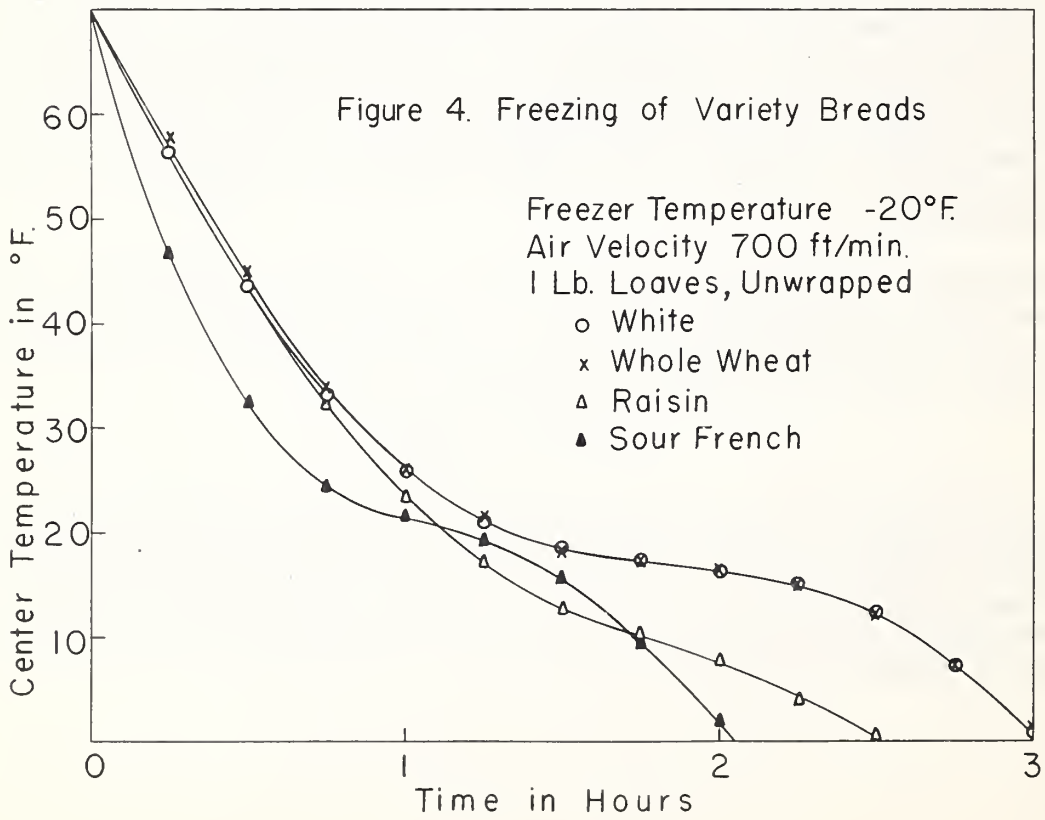
Figure 4. Freezing of Variety Breads
Freezer Temperature -20°F.
Air Velocity 700 ft/min.
1 Lb. Loaves, Unwrapped
o White
x Whole Wheat
Δ Raisin
▲ Sour French
Center Temperature in °F.
60
50
40
30
20
10
0
1
2
3
Time in Hours

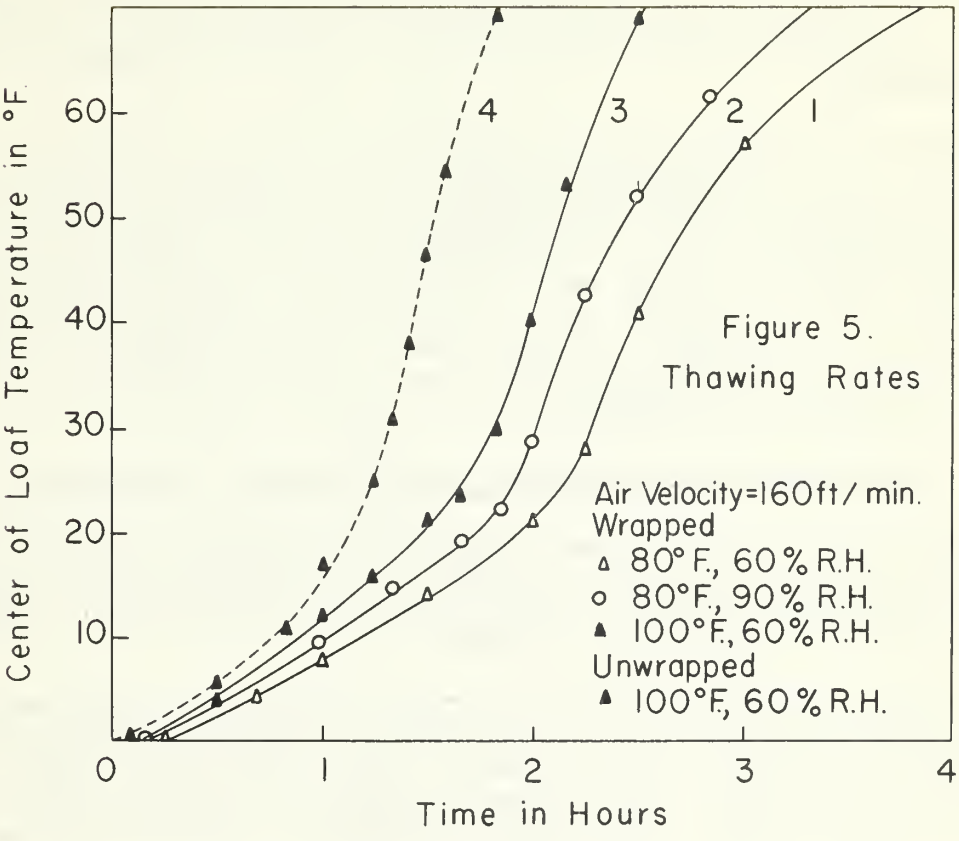


Figure 5.
Thawing Rates

Figure 5 shows typical defrosting curves found in the study. The first traces the temperature rise in wrapped bread defrosted by gently moving air at 80°F. and about 60% relative humidity. The second curve shows the result when air temperature was the same but relative humidity was about 90%. The third was obtained with relative humidity at the lower level and air temperature raised to 100°F. Both were important in defrosting bread. As either was increased the water content (absolute humidity) of the air was likewise increased and the heat-carrying capacity of the air became greater. The fourth curve (Figure 5) represents an unwrapped loaf at 100°F. and about 60% relative humidity. As with freezing, a wrapper exerts a marked insulating effect during defrosting.

Condensation on the wrapper during defrosting was relatively minor with the two lower humidity conditions and moisture that condensed soon evaporated. At the higher relative humidity some moisture remained on the wrapper at the end of the defrosting time. The loaf defrosted without a wrapper absorbed approximately half an ounce of moisture during the regular defrosting time, but continued exposure to warm air caused the loaf eventually to lose more moisture than it had gained. A gain or loss in weight during defrosting of unwrapped items is therefore shown to depend on air temperature, relative humidity, and duration of exposure.

## Effect of Freezing and Defrosting Times on Crumb Firmness

Other workers (1,5,6) have stressed rapidity of freezing and defrosting bread to preserve original freshness, but little published information exists on the difference that variations in the procedures actually cause. Tables 1 and 2 show some observations on this point.

Firmness values for bread frozen and defrosted at different rates were obtained with the Baker Compressimeter on slices cut 3/4 inch thick in a miter box. Ten slices from the middle of each of three loaves were used to obtain the average values shown. Bread frozen at different rates was defrosted in a standard time of 5 hours, and bread defrosted at different rates had been frozen in a standard time of 80 minutes.

Table 1 shows that freezing time exerts a very significant effect on the firmness of the crumb. Bread frozen as rapidly as possible with the existing facilities (without a wrapper and crosswise to a high-velocity air blast at -20°F., as described above) increased only a small amount in firmness; and a portion of this increase occurred during the defrosting process which was necessary to prepare the samples for measurement. The longer freezing times produced a firming effect equivalent to that caused in unfrozen bread by more than 24 hours' storage at room temperature.

Table 2 shows that defrosting time is much less important than freezing time in causing bread crumb to become firm. Only part of the relatively small increases in firmness for the defrosting times is due to defrosting, because freezing the samples for testing caused a certain amount of firming.

Table 1. Effect of Freezing Time on Crumb Firmness

| Freezing time, hr. | Average increases in firmness, g/4 mm. compression 1/ |
|---|---|
| 0.5 | 16 |
| 1.5 | 32 |
| 3 | 57 |
| 7 | 71 |

1/ Minimum significant difference at 5% point = 11 g.

Table 2. Effect of Defrosting Time on Crumb Firmness

| Defrosting time, hr. | Average increases in firmness, g./ 4 mm. compression 1/ |
|---|---|
| 2.3 | 13 |
| 5.5 | 32 |
| 10.8 | 31 |

1/ Minimum significant difference at 5% point = 12 g.

Table 3. Effect of Storage Temperature on Firmness Increases in Frozen Bread

| Storage temperature, °F. | Length of storage, days | Average increases in firmness, g./4 mm. compression |
|---|---|---|
| 15 | 3 | 27 |
| 10 | 24 | 14 |
| 0 | 24 | 0 |
| -10 | 24 | 0 |

Table 4. Effect of Age of Bread at Time of Freezing on Freshness Evaluation

| Age at time of freezing, hr. | Average rank by taste panel 1/ | Average firmness, g./4mm.compression |
|---|---|---|
| 4 | 1.3 | 72 |
| 11 | 1.8 | 84 |
| 34 | 2.9 | 106 |

1/ Minimum significant difference at 1% point = 0.4.

## Effect of Storage Temperature

Unquestionably the act of freezing and defrosting bread causes the crumb to become significantly firmer even though the processes are conducted rapidly. It is generally assumed that firming changes cease once the bread is frozen and that it can be stored for considerable lengths of time without additional change. On the other hand, there have been reports that flavor changes do occur if storage is unduly prolonged (2,3) and that storage temperatures above 10°F. should be avoided (1,5,6) because of other unspecified changes which can occur above this temperature. Results obtained in the present investigations confirm the latter point, at least with respect to firmness measurements. For instance, the values in Table 3 show that the crumb of one lot of bread stored for 3 days at 15°F. increased in firmness by approximately 27 grams/4 mm. depression, as measured on the Baker Compressimeter. Another lot stored at 10°F. for 24 days increased about 14 grams/4 mm. depression, but bread stored at 0°F. or -10°F. showed no increase in firmness after 24 days of storage. It was concluded, therefore, that a proper storage temperature for frozen bread should be 0°F. or below for extended storage or 10°F. and below for storage periods of less than a week or so.

An interesting observation concerning bread at temperatures below its freezing point is that the loaves do not become rigid to the touch until their temperature is down to about 0°F. At 10°F., for instance, they are still slightly compressible when squeezed by the fingers. It is tempting to conclude that the firming changes which occur at very low rates down to about 10°F. are related somehow to this lack of rigidity between the freezing temperature and 0°F.

## Taste-Panel Judgments on Firming Changes

The foregoing discussion has indicated changes in firmness to be expected from freezing and defrosting bread at different rates. Results in Table 4 indicate that a taste panel is surprisingly sensitive to such differences in crumb firmness. Three lots of oven-fresh bread were frozen in a standard manner after different times of standing at room temperature. The samples were then thawed by a standard procedure and presented to panel judges who were asked to rank them from the standpoint of freshness, as judged by either flavor, softness, or both. Most could not distinguish between samples on the basis of flavor alone.

Panel judgments and compressimeter values were closely parallel, and both methods showed a significant distinction between breads frozen 4 and 11 hours after removal from the oven. When samples of the same bread were held at room temperature for 48 hours after they had been defrosted, the panel easily picked out the bread frozen at 4 hours of age but could not distinguish between the samples which had been frozen at 11 and 34 hours of age. This experiment confirms the generally recognized advisability of freezing bread as soon as possible after it leaves the oven and indicates further that it should be frozen and defrosted as rapidly as is consistent with other economic considerations.

## Wrappers

A major function of wrappers for bakery goods is to minimize undesirable moisture changes. Loss of moisture from a product during freezing is generally considered a matter for concern because cold air is very dry air. Results obtained indicate, however, that this is not such an acute problem with freshly baked bread. For instance, unwrapped bread placed in the freezer approximately 3 hours after leaving the oven was found to lose an average of only 4 grams of moisture during a 5-hour exposure to air at -20°F. and 1,200 ft./min. velocity. During subsequent storage at 0°F., the loaves lost approximately 2 grams of additional moisture per day, so that at the end of 17 days the average total loss was about an ounce.

Probable reasons for such small moisture losses include the fact that the crust of freshly baked bread is still quite dry so that moisture within the loaf is hampered in its escape. A conclusion from this experiment is that freshly baked bread can be safely frozen unwrapped but that a wrapper is essential to prevent serious subsequent moisture losses if bread is to be stored more than a few days.

Most wrapping materials designed for the purpose are adequate to prevent a significant loss of moisture under the conditions and duration of storage to which bread is apt to be subjected. Bread, however, presents a few problems not common to many other frozen foodstuffs. A loaf of bread shrinks approximately 6 percent in girth during freezing, and wrappers fit loosely. A desirable wrapper, therefore, should be both sturdy and flexible at low temperatures to minimize wrinkling or crumpling due to even ordinary handling while it is still frozen. Another important period with respect to damage to the wrapper from handling is the defrosting period, when condensed moisture is on the wrapper. Any tendency to absorb this moisture and soften will cause marking by the fingers during handling. Absorption of moisture alone can cause pebbling or wrinkling of some wrappers even though the bread may not be handled until after it is again dry. With adequate care, however, it appears that currently used wrapping materials can be employed for the freezing of bread, but modifications of these materials, which are more flexible and resistant to the effects of moisture, would seem more desirable, depending somewhat on the actual conditions under which they would be used.

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